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For: Apparatus for Rapid PN Code Acquisition

## APPARATUS FOR RAPID PN CODE ACQUISITION

## BACKGROUND OF THE INVENTION

## 1. Field of the Invention

The present invention relates to communications and, more particularly, to code division multiple access techniques.

## 2. Prior Art

Referring now to Fig. 2 there is shown a block diagram of a direct sequence coded spread spectrum system. As shown in the diagram a carrier signal generated by carrier generator 80 is modulated at mixer 98 by data 82. The data modulation operates at a rate determined by code clock divided by spreading gain  $G$  84. The modulated signal is further mixed 99 with a code generated by the pseudo-noise (PN) code generator 86 operating at a clock rate determined by code clock 85. The transmitter 88 transmits the twice modulated signal via antenna 90. The transmitted signal is received by receiver 94 via antenna 92. The received signal is correlated with a PN code generated by PN code generator 106 at mixer 96. A signal passing correlation is then demodulated by mixing the correlated signal with a local carrier recovery 104 in mixer 100. The transmitted data and clock rate are recovered in data processing 102 and 108, respectively. The recovered data 110 is passed to the remainder of the system for further processing while the recovered clock is used to drive the PN code generator 106 and the data processing 102 after being reduced by spreading gain  $G$  112. The spreading gain is determined by the PN code rate  $R_c$  divided by the message rate  $R_b$ . The time duration of

Rc is  $1/R_c = T_c$  and is referred to as a chip. In general, when changing from a low-rate PN code to a higher rate PN code, where  $T_{c_{low}}$  and  $T_{c_{high}}$  are the chip times, respectively, the spreading gain is multiplied by the  
5 ratio  $T_{c_{low}} / T_{c_{high}}$ . The average time that is required to complete a search for PN timing is  $k/R_b$  per chip of uncertainty, where  $k$  is some constant of proportionality based on the search technique. Hence, if we do the initial search using a shorter low-rate PN and then  
10 synchronously switch to a higher-rate PN the average search time can be reduced by as much as  $T_{c_{low}} / T_{c_{high}}$ .

#### SUMMARY OF THE INVENTION

In accordance with one method of the present invention, a method for determining a signal code. The method  
15 comprising steps of acquiring and correlating a signal with a first code sequence and achieving a timing lock in response to the step of correlating the signal with a first code sequence. Also in response to the correlated signal the receiver transmits an acknowledgement signal  
20 to a transmitter of the signal where upon the receiver and transmitter change from the first code sequence to a second code sequence.

In accordance with one embodiment of the present invention a signal code acquisition system comprising a  
25 first transceiver and a first multi-rate code generator connected to the first transceiver; a second transceiver responsive to the first transceiver; and a second multi-rate code generator connected to the second transceiver.

In accordance with another method of the present invention a method of determining a coded signal, the method comprising steps of: transmitting a first coded signal from a transmitter system; receiving the first coded signal on a receiver system; calculating a probability of detection of the first coded signal; and changing the first coded signal to a second coded signal responsive to the probability of detection (PD) of the first coded signal.

#### BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing aspects and other features of the present invention are explained in the following description, taken in connection with the accompanying drawings, wherein:

FIG. 1 is a perspective view of a satellite communications system and a base station communications system to which the satellite communications system is bidirectionally coupled through a wireless RF link and incorporates features of this invention;

Fig. 2 is a block diagram of a direct sequence PN coded system;

Fig. 3 is a block diagram of multi-rate PN coded system illustrating an embodiment of this invention;

Fig. 4 is a flow chart illustrating one method of the present invention; and

Fig. 5 is a flow chart illustrating an alternative method of the present invention.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Although the present invention will be described with  
5 reference to the embodiments shown in the drawings, it  
should be understood that the present invention can be  
embodied in many alternate forms of embodiments. In  
addition, any suitable size, shape or type of elements or  
materials could be used.

10 Reference is first made to Figs. 1 for illustrating a  
base station 10, such as but not limited to satellite  
communications base station, that is suitable for  
practicing this invention. The base station 10 includes  
an antenna 12 for transmitting signals to and for  
15 receiving signals from a base orbiting satellite 30.

Referring now to Figs. 1 and 3. The base station 10 and  
the orbiting satellite 30 include circuitry for  
transmitting coded signals 51 and circuitry for decoding  
received signals 61. The circuitry for transmitting coded  
20 signals includes a multi-rate pseudo-noise (PN) code  
generator 52, transmitting timing and control circuitry  
50, a transmitter 54, data source 56, and an antenna 58.  
The circuitry for receiving the coded signal includes a  
receiver front end 62, a synchronization detector 68,  
25 receiving timing and control circuitry 66, a multi-rate  
PN code generator 64, data estimator 70, and an antenna  
60 for receiving signals. The coding method for this  
invention is assumed to be based on CDMA such as is known  
from or that is similar to air standards IS-95 PCS or W-

CDMA, although the teaching of this invention is not intended to be limited only to that particular type of CDMA system. The present invention, providing significant reduction in PN code acquisition time over conventional  
 5 PN code acquisition time, could be used with any suitable type of radio telephone system or suitable electronic device

Referring now to Figs. 3 and 4, there is shown a block diagram of a transmitter and receiver system and a method  
 10 flow chart incorporating features of the present invention. The transmitter 54 transmits data 56 modulated by a carrier signal and further modulated by multi-rate PN code generator 52 through antenna 58. The PN code generator 52 is controlled by timing and control  
 15 circuitry 50. The receiver 62 receives the twice modulated carrier signal 120 via antenna 60. The signal is auto-correlated with a PN code 122 supplied by multi-rate PN code generator 64. If the signal auto-correlation peak is found then the signal is a desired signal and is  
 20 further demodulated to retrieve data 126 and recover synchronization 68. The synchronization then tracks the PN timing 128 via the timing and control circuitry 66 and signals the transmitting system and the receiving system to contemporaneously shift to a higher rate PN code 132  
 25 via their respective multi-rate PN generators 52, 64. Thus, for purposes of illustration, if the lower rate PN code duration is designated as  $T_{C_{low}}$  and the higher rate PN code duration is designated as  $T_{C_{high}}$  the search time, or PN code acquisition time, is reduced by a factor of  
 30  $T_{C_{low}}/T_{C_{high}}$ . For example, in the prior art the search time for a PN code duration is the processing gain times an uncertainty factor. Using the lower code duration  $T_{C_{low}}$ ,

the processing gain is  $T_b / T_{C_{low}}$ , where  $T_b$  is the message bit duration. Without the current invention the processing gain when shifting to a higher rate PN code would be  $T_b / T_{C_{high}}$ . Assuming that  $T_{C_{high}}$  is some multiple  
 5  $1/M$  of  $T_{C_{low}}$  then the processing gain equation can be rewritten as  $T_b * M / T_{C_{low}}$ . Then, assuming an average search rate of  $k/R_b$  per chip of uncertainty, the PN search time is then  $(M * T_b / T_{C_{low}}) * k/R_b$ , where  $R_b$  is the message bit rate. Thus, the average search time has been increased by  
 10 a factor of  $M$  when shifting from a low rate PN code to a high rate PN code. By contrast, the current invention uses a narrow bandwidth timing recovery loop to maintain the timing lock achieved during the acquisition of the first or lower rate PN code while both multi-rate  
 15 generators contemporaneously shift to the higher rate PN code. Since the timing lock is maintained the search time equation is the original gain times the uncertainty factor, which in this example is  $T_b / T_{C_{low}} * (k/R_b)$ . Thus, the average search rate has been reduced by a factor  $M$   
 20 when shifting from the lower rate PN code to the higher rate PN code.

Referring now to Fig. 5 there is shown a flow chart of a second method of the present invention. The transmitter transmits 140 a low rate PN modulated signal. The  
 25 transmitter calculates a probability of detection (PD) 142 by the receiver 62. If the PD is greater than a predetermined amount 144 the transmitter will shift 146 the multi-rate PN generator 52 to a higher rate PN code after a predetermined amount of time or event. Meanwhile,  
 30 the receiver 62 receives 160 the signal and auto-correlates 158 with the low rate PN code generated by the multi-rate PN generator 64. If the signal auto-

correlation peak is found 156 then the data is decoded  
154 and the synchronization detector 68 and the timing  
and control circuitry lock 152 on to the signal timing .  
The receiver also calculates the PD and if greater than  
5 the predetermined amount will shift 150 the multi-rate  
PN generator 64 to the higher PN code 148 after the  
predetermined amount of time or event. The processing  
gain and search times are calculated as before.

It should be understood that the foregoing description is  
10 only illustrative of the invention. Various alternatives  
and modifications can be devised by those skilled in the  
art without departing from the invention. Accordingly,  
the present invention is intended to embrace all such  
alternatives, modifications and variances which fall  
15 within the scope of the appended claims.